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concerning the interaction between science and technology

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It is generally recognized that new concepts and technologies important to society in general, and to DoD in particular, often depend on new knowledge and understanding generated in the scientific-research activities of the world's universities, industries, and other research organizations. There is also a growing realization of the importance of the interactions with advanced technology in achieving the internal goals of science. However, the nature of these mutually beneficial relationships are not well understood, partly because of the diverse and diffuse nature of the interactions, and partly because of the lack of attention given to understanding them.

There are several important considerations, ranging from the optimization of the organizational arrangements for research-and-development activities to the balance of funds between basic research and other RDT&E activities, which make it highly desirable to obtain an increasingly sophisticated understanding of this relationship in order that the best interests of the Nation will be represented. AFOSR recently published a report (1) that contributes to this required understanding.

The report describes a recent AFOSR study which has provided us with a large increase in specific information showing how the Air Force has benefited from the AFOSR program. In the course of this study, which included a survey conducted by contacting a group of previously supported AFOSR principal investigators and other knowledgeable persons to obtain additional information on the utilization of the results of the AFOSR research programs, we collected and analyzed information about the interaction between science and technology.

We find that it is helpful, both in describing AFOSR and its accomplishments, and in discussing the interaction between science and technology, to divide research-and-development activity into two broad categories--Phenomena-Oriented Science, and Technology, as illustrated in Figure 1. In technology, creative efforts are primarily concerned with synthesis, that is, the integration of previously existing knowledge components into operational capability--for example, systems, devices, processes, methods, and materials. In contrast, phenomena-oriented science is more heavily

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concerned with the origins of the knowledge components themselves.

Note in the figure that both applied science and engineering development are classified as parts of technology. Applied science is so named because its goal is some sort of application of scientific principles. Thus, the name comes from the goal. A phenomena-oriented scientist concerns himself with the elucidation of natural phenomena. Thus his goal is the study of phenomena, and consequently it is reasonable to call his activity "phenomena-oriented science."

As new phenomena are understood, this new knowledge is made available to the scientific and technological communities in many ways. However, it is important to note that the new information becomes known by a scientist's peers in the world scientific community much sooner than by other groups, particularly those associated primarily with technology. Important new knowledge, such as that being accumulated in the scientific fields that AFOSR is helping to colonize, is known to members of the "invisible college," that is, to those researchers active in a particular segment of the research front, well in advance of any formal written publication. Thus, new science forges ahead, relatively independent of an ambient technology.

Similarly, technology usually feeds upon technology, in the presence of an ambient science. It has become increasingly clear, especially to the historians of science, that technological events are usually initiated within technology. This means that it is usually difficult to establish a unique correlation between an important technological event and one within phenomena-oriented science. One well-known exception is nuclear

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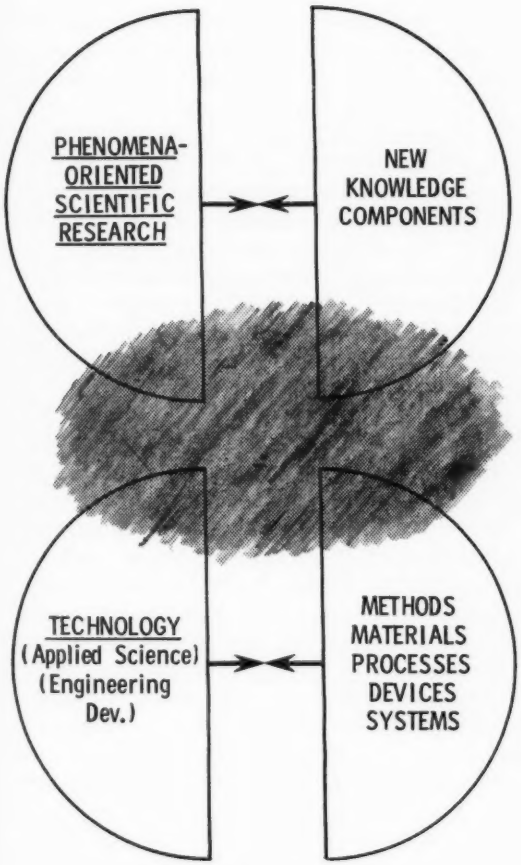

FIG. 1

power, and its origin in the discovery of nuclear fission. Our study shows that one does not usually find phenomena-oriented research producing a new and unexpected opportunity, which then stimulates a new engineering opportunity. (This observation is consistent with those of other recent studies on the interaction of science and technology [2, 3, 4].) Instead, we find phenomena-oriented research supporting technology in many other important ways.

Thus, the gross picture is that technology usually feeds upon technology, and phenomena-oriented science usually feeds upon phenomena-oriented science. However, at the same time we find that there is a strong important interaction (almost a symbiosis) between the two spheres of activity, as symbolized by the overlap in the figure.

We are impressed by both the large number and great variety of AFOSR accomplishments that can be identified as important contributions to the Air Force. Our success in finding utilization through this study shows us that a large amount of additional specifics could be accumulated, if necessary. Examples of areas of utilization will illustrate the great variety.

We find that a very important area of contribution has been through helping to colonize many important scientific areas which have turned out to have special relevance to the Air Force, inasmuch as they are generally recognized as underlying important Air Force applications. Colonizing may be described as increasing the chance of important discovery in an area deemed to hold promise for the Air Force by "raising the temperature" of the world's scientific activity in that field. Through the judicious support of phenomena-oriented research and other activities, such as symposia, the Air Force has helped to colonize the activity in numerous research areas, with the result that Air Force research support, amplified by that promoted by non-Air Force funds, has very significantly affected the rate of development of important scientific areas. Concurrently, the AFOSR program has helped immeasurably by educating many thousands of graduate students who, later on, have gone to work in Air Force contractor or in-house activities, equipped with the knowledge and skills particularly pertinent to Air Force work because of their previous Air Force association.

We also find that we can identify many specific examples where AFOSR-supported phenomena-oriented research has provided important support of Air Force weapons-acquisition programs at all phases of the research, development, and engineering cycle. We find this input through new or improved manufacturing techniques, design techniques, instrumentation, and weapons-system component concepts, to mention a few cases. The MAB study (2) on research-engineering interaction has also noted a similar diversity in the types of important

interactions occurring between science and technology.

We also find that many scientists supported by AFOSR are consultants for DoD contractors, and for in-house research-and-development activities. In a very real sense, AFOSR support helps these persons achieve and maintain their expertise while they contribute direct practical help to the DoD.

It is found that the science-technology interactions leading to the utilization of phenomena-oriented research are usually initiated by persons who, having a problem which requires new knowledge, seek this knowledge and the solution to their problem in the results of prior research. The scientists who are consulted also play a very key role on their side of the dialogue, providing knowledge and interpretation from their field.

The fact that new knowledge originating in phenomena-oriented research often has implicit in it important new opportunities for exploitation means that, when these can be recognized on the research side, great advantages, particularly in timing, can be realized. This is an important area for increased attention by phenomena-oriented research activities, towards the end that initiative can be successfully taken by the scientist more frequently.

Our conclusion from these studies is that the conventional picture, which emphasizes a process whereby unique scientific events are followed in an orderly manner by applied research, development, etc., is usually not borne out. Since this picture appears to be the exception rather than the rule, it is misleading to attempt to elucidate the contribution of phenomena-oriented science by studying this process primarily. In fact, the failure to observe a large number of such cases could lead to a nonobjective backlash in which the real (and very important) process involving the flow of a great number of items of information across the technology-science interface may not be recognized.

Any study, for example, of a series of weapons systems, aimed at isolating the points of origin (such as identifying key events) will often reveal them to lie within technology. A dangerous conclusion which might be drawn from such results is that science (especially current science) is of little help in the development of weapons systems. Actually, what our studies show (and the same conclusions have been reached by other investigators of this subject) is that current science is exceedingly important to the development process, but not so much from the viewpoint of origin as from the effects of a continuous contribution of many useful items of information. It is this subject which should be the primary object of study, when the impact of research is to be evaluated, rather than the question of origin.

Similarly, it would be a mistake to try to have a large fraction of the DoD phenomena-oriented research programs arranged to support specified technological goals, such as the exploratory-development projects of the DoD. This type of programming will not work out since its success depends on direct, rather simple relationships between the science program and technology, which do not exist. For example, if AFOSR were to use this type of programming primarily, looking back from technological needs toward science, it would end up with more applied science (or technology, in terms of this model). While this type of activity would be very valuable, it would simply be adding to the excellent applied-research programs already being conducted by the Research and Technology Division (AFSC) and others, and AFOSR would not be performing its assigned mission. Rather, the role of AFOSR is to capitalize on its strong identity with phenomena-oriented research to bring a new type of capability to Air Force research-and-development activities, thus complementing the many excellent technological activities.

This knowledge of the interaction between science and technology provides guidance for the emphasis of AFOSR's mission. We find it very helpful, in thinking about our mission, to describe our organization as a "Research Institute." This Institute includes our AFOSR staff (the "Research Institute Managers"), our various advisors and, most important of all, the people who do the research. The "AFOSR Research Institute" can be visualized as an activity which,

because it is intimately involved with both the scientific community and the Air Force, provides an effective interface between these two communities. AFOSR has a great ability to attract the interest of the world's top scientific talent. This is because it is a science-oriented organization with the well-established reputation, in the scientific community, of being a good research agency with which to work. At the same time AFOSR staff members have the mission, experience and techniques required for identifying DoD problem areas, and translating scientific knowledge and understanding into results for DoD users. In providing this interface, the "AFOSR Research Institute" not only accomplishes research, but also provides for communication between the scientific community and the using agencies.

The selection of areas in which to accomplish Air Force-supported, phenomena-oriented research may be motivated by helping a development group solve certain classes of relatively short-term technical problems through a fuller understanding of the phenomena behind them--or, as is more common, by seeking to open new fields of science which hold high promise for the generation of new knowledge needed to help evolve future technologies.

The communication provided by the "AFOSR Research Institute" is two-directional--needs to the research program, and scientific information to the users. We provide this communication by engaging in many types of coupling activities. For example, part of what we purchase through contracts and grants is primarily designed to provide communication. This part refers not only to the symposia we sponsor, but also to the connecting-type research which allows us to keep abreast of a variety of those scientific areas largely supported by other agencies, in which rapidly emerging scientific developments of possible importance to the Air Force are taking place.

Some of the most meaningful coupling activities are those which directly involve the research scientists AFOSR has under contract. We find that scientists around the country are very able and willing to participate directly in Air Force activities in many ways. The following are a few examples: trips to Air Force installations to perform consulting services; membership on ad-hoc groups to study the feasibility of various exploratory-development programs; state-of-the-art reviews, either oral or written; special-purpose symposia which are specifically designed to bring technologists and scientists together; special lecture tours; the performance of feasibility studies on research phenomena to package them in a form more likely to be useful; and direct consultation with the aerospace industries. Many basic-research scientists receive great satisfaction and stimulation from the important direct contributions they make to the DoD establishment, in addition to the significant contributions they are making through their own research.

It is clear that any technology-dependent organization, such as the Air Force, must have the capability to receive the greatest possible benefits from the world's phenomena-oriented research activities. AFOSR, the major Air Force science-oriented activity assigned this function, meets two special challenges of a continuing nature as it helps provide this capability. One is the choosing of the appropriate areas in which to support research--and the other is the catalyzing of the very important interaction between science and technology. Both activities are strengthened through an improved understanding of the important symbiosis which exists between phenomena-oriented science and technology.

REFERENCES

(1) Price, W. J., W. G. Ashley and J. P. Martino, Relating the Accomplishments of AFOSR to the Needs of the Air Force, AFOSR 66-2423, November 1966; also to be published in the Proceedings of the MIT Conference on Human Factors in the Transfer of Technology, edited by W. H. Gruber.

(2) Tannenbaum, M. and Committee Members, Report of the Ad Hoc Committee on Principles of Research-Engineering Interaction, National Academy of Sciences-National Research Council, Materials Advisory Board, Publication MAB-222-M, July 1966.

(3) Price, Derek de Solla, "Is Technology Historically Independent of Science? A Study in Statistical Historiography," Technology and Culture, V6, N4, PP553-568, Fall 1965.

(4) DoD Project Hindsight Reports.

VAPOR-PHASE CALORIMETRY

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The use of calorimetry to determine heats of reaction and, indirectly, heats of formation, is an old established art. The previous work was mostly in the field of bomb calorimetry, in which the reactants are ignited under high pressure in a container known as a "bomb." In this method, the entire molecule is blasted apart by violent oxidation. As the accuracy of this method depends on maintaining adiabatic conditions (no heat gained from or lost to the surroundings), the reaction studied must be rapid. For obvious reasons, it should also be reproducible in terms of completeness and products. Commonly, hydrocarbons are combusted in oxygen to produce water and carbon dioxide. The heat released in the combustion is then determined from the temperature increase of the water which surrounds the bomb. The bomb-calorimetry method is restricted to a small group of reactions. In addition, the data obtained are a result of the over-all reaction.

Dr. Joseph Park and Dr. John Lacher, of the University of Colorado, have been carrying out research in thermochemical-data determination under AFOSR sponsorship since 1954. Their recently developed vapor-phase-calorimetry method has been described by Dr. Guy Waddington, Director, Office of Critical Tables, National Academy of Sciences, as "one of surgical precision, whereas the bomb method is a butcher-like dismemberment." The Park and Lacher calorimeter is an isothermal-flow calorimeter in which the reactants are introduced into a tantalum reaction chamber, mixed, and passed over a platinum catalyst. The reaction chamber rests in a heat-transfer bath which is cooled to a constant temperature by bubbling an inert gas through it. A steady state is obtained when the cooling rate becomes constant, and there is a consistency of products. This may take as long as 12 hours, even when reactions are run at 250 degrees Centigrade. The heat release is then determined from a mass measurement of the amount of volatile calorimeter fluid which has been vaporized in a period of time. The necessary analysis of the products is accomplished by gas-chromatographic separation, followed by infrared analysis. The vapor-phase-calorimetric technique allows the measurement of heats of reaction for a new and large class of reactions.

Park and Lacher are presently concentrating their efforts on reactions which involve the addition of hydrogen, halogens, or hydrohalogen acids to individual double bonds, or which involve the simple substitution of a halogen. The reactants being studied for the Directorate of Chemical Sciences, AFOSR, are fluorine-containing hydrocarbons. Many of these compounds are not available in the large amounts required for this method, and must first be synthesized and purified by Dr. Park. As distinguished from combustion reactions, these reactions yield information which can be related directly to molecular happenings at precisely located parts of a molecule. Eventually, it should be possible to determine the individual bond energies at the site of the addition or substitution reaction, and the nature of their variation from compound to compound. The next step would be to correlate this variation with their electronic environment and to possibly develop a general theory for the prediction of thermochemical data.

This AFOSR-sponsored program has already generated significant amounts of thermochemical data for the literature. Future investigators, utilizing any of the many compounds studied, will benefit from the painstaking work accomplished by this project. Its success is due in large measure to the bringing together of two quite diverse scientific talents--Dr. Park, an outstanding organic chemist, and Dr. Lacher, an imaginative and precise physical chemist. ★

rocket tracking systems for launchings in remote locations

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Most rockets are launched from established launch sites where the range support needed for tracking and for receiving telemetered information from the rocket is available. The rocket-borne portion of the electronics system is kept simple relative to the larger and more complex ground instrumentation. However, trade-offs can be made and, with proper design of the rocket-borne electronics, it is possible to launch rockets from remote sites where no range support is available. Only a minimum of conventional ground receiving equipment is necessary.

In June, AFCRL tested two such rocket-borne systems. The systems were flown in a NIRO rocket. The tests were made to check the accuracy and reliability of the systems. One of the systems provides tracking as well as telemetering information in the same unit, thereby reducing the number of components and the additional weight and drag of multiple antennas. This system requires slight modification of a standard airborne transmitter with the addition of an ultrastable reference oscillator which is ruggedized and temperature-controlled. This oscillator replaces the regular crystal in the PM-type telemetering transmitter. The ground receiving part of this system is somewhat more complicated and is capable of tracking the received frequency to a high degree of accuracy. An ultrastable reference oscillator--the same type as in the airborne transmitter--is included in the receiver circuitry. This enables a Doppler frequency component, which is used to compute slant range, to be extracted from the received signal. The receiver is also capable of detecting the telemetered data.

The second system that was tested is an inexpensive solid-state oscillator that can be frequency-modulated. This unit provides the tracking signal for an unmodified meteorological tracker, the GMD II, which gives azimuth elevation and ranging information.

All systems worked very well, yielding continuous tracking and telemetering data during the entire rocket flight (100 miles zenith). The data from the two systems have been compared and are in good agreement. The results are being checked with those obtained from the FPS-16 radar which is used for tracking rockets at the major ranges.

CONTINUUM MECHANICS OF BIOMEDICAL SYSTEMS

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The methods of continuum mechanics are valuable tools for solving some of the problems in the rapidly growing field of bioengineering. These problems, in turn, provide a powerful incentive for the further study of finite elasticity, theoretical rheology, non-Newtonian flow, and the dynamics of nonconservative systems. In fact, many of the advances in the solution of current biomechanical problems will constitute an enrichment to applied mechanics.

The Mechanics Division of AFOSR has sponsored a number of research efforts which, although their prime purpose was to apply the general methods of solid and fluid mechanics to solving bioengineering problems, have illuminated new areas of basic continuum mechanics. These efforts include an experimental study by Dr. A. H. Sacks of the Itek Corporation on the flow of density-matched rigid sphere suspensions in rigid cylindrical tubes at low Reynolds numbers

which, in some cases, bears a strong resemblance to the flow in living blood vessels. (1) Another such effort is an experimental and theoretical study by R. T. Jones of the Avco-Everett Research Laboratory on the significant hydrodynamic factors affecting the clotting of blood. Under study are such parameters as 1) the ratio of characteristic flow times to chemical-reaction rate times, and 2) the importance of the shear associated with the non-Newtonian viscosity of blood. Also under sponsorship are contracts where the portion of the work with biomedical implications comprises a small but nevertheless important part of the total effort. In this category is the work of Professor Simon Ostrach of the Case Institute of Technology who will investigate the effect of gravitational convection resulting from concentration or thermal gradients inside a flexible sphere. The results of this study, which couples solid and fluid mechanics and, in addition, involves diffusional phenomena, may explain observed pressure changes in the eye, and bring to light important considerations concerning eye hygiene in a zero-gravity environment. The research of Dr. E. R. van Driest of North American Aviation on the effects of surface roughness, pressure gradient, and free-stream turbulence on stability and boundary-layer transition (2-5) is an example of AFOSR-sponsored work which, although it influenced the design of the XB-70, nevertheless is so universal that it has applications in the dynamics of blood flow.

A unified approach to the above-mentioned and other AFOSR work with biomedical implications will be presented at a later date. What will be described here is the work only of the AFOSR-sponsored scientist, Professor Y. C. Fung of the California Institute of Technology. A previous article in the OAR Research Review (6) referred to much-needed work then under way on experimentally determining the elastic properties of blood vessels. Professor Fung, working together with physiologist Professor W. Frasher and physician Dr. Kato of the Loma Linda Medical University, designed and fabricated a special testing machine and recording equipment for determining the stress, deformation, and deformation rate of the arteries and veins of dogs tested in a physiological bath under conditions which assure the living state of the vessels. Typical diameters of the blood vessels tested were 0.16 cm for femoral arteries, 0.35 cm for carotid arteries, and 0.50 cm for jugular veins. The results, analyzed in accordance with large deformation theory, are considered to be the most definitive so far obtained in the determination of the mechanical properties of blood vessels. Not only the elastic properties, but also the hysteresis response to cyclic loading were carefully analyzed. A complete report on the results is expected to be published in the near future.

Even though much research on the large blood vessels remains to be performed, what has already been accomplished is substantial in comparison to the small amount of work done in the more difficult area of the small microscopic blood vessels, the capillaries. In analogy with the arteries and veins, the classical concept of the capillary blood vessel is an elastic tube in a fluid medium. However, difficulties were encountered when this concept was applied to explain the experimental results of Baez, Baez, and Lamport, (7) who microscopically examined the distensibility of capillaries while the driving hydraulic pressure was varied over a range of 20 to 200 mm Hg. It was found that the capillaries (8 to 10 micra diameter) behaved as rigid tubes. If the rigidity of the capillaries were to be explained by the tube-in-fluid concept, then the required modulus of rigidity of the wall is too high to be probable. (8) An alternative hypothesis put forward by Professor Fung is that the capillaries derive most of their support from their immediate surroundings which behave as a solid gel capable of resisting shear strain elastically or plastically. The capillaries would thus behave more like tunnels in an elastic medium of connective tissue than as tubes in a fluid.

As a first step in testing Fung's hypothesis, which is physiologically plausible, it appeared desirable to determine some of the elastic properties of the capillary environment. The contribution of the surrounding

tissue to the support of the capillaries could then be calculated under the hypothesis that these small blood vessels are in direct contact with the tissues. Sizeable areas of the mesentery of a large laboratory animal such as a rabbit do not contain large blood vessels and have very few capillaries, but are in all other respects similar to the rest of the mesentery. For this reason, Professors Fung, Zweifach, and Intaglietta carried out tests on the avascular regions of the mesentery of the rabbit. (The results are presented in References 8 and 9.) The mesentery of the rabbit was found to be able to resist shear very well under a torsion test, which is consistent with the behavior of a gel rather than a liquid. It was also found to have a modulus of rigidity smaller than, but of the same order of magnitude as, the large arteries and veins. Its stress-strain relationship is nonlinear, with a strong tendency to harden at larger strains. Use of the experimental results obtained thus far supplied a natural explanation of the earlier distensibility measurements of Reference 7. The hypothesis that capillaries behave as tunnels in a solid gel must, however, be regarded as tentative. Professor Fung will test further consequences of this hypothesis to strengthen the evidence that the capillary bed is indeed gelled.

Another problem area in bioengineering relates to red blood cells whose mechanical properties are not yet fully known, even though they have been subjected to physical and chemical investigations. Some important questions of significance to basic science, as well as to aeromedicine, are: How are the stresses and strains transmitted in a red cell? How do stresses develop in the red cell in a shear flow? How strong are the cell walls? How does one predict the rupture or destruction of red blood cells with respect to mechanical handling such as in a heart-lung machine? A series of quantitative investigations will be undertaken by Professor Fung to answer these questions.

In his talk (9) at the Microcirculation Society, Professor Fung considered, from the viewpoint of theoretical mechanics, the question as to whether the interior of the red blood cell is in the state of a fluid or a solid. He showed that under the assumption of a liquid interior there can be deduced, from first principles and the fact that the red blood cell has a biconcave geometry, that 1) the pressure differential across the cell membrane is very small; 2) the membrane is unstressed at the natural state; 3) the positive and negative critical buckling pressures of the cell are very small; and 4) a great variety of shape deformations at constant volume is possible which do not change the membrane stresses and the pressure differential. The pressure differential cannot be changed by varying the external hydrostatic pressure, but can be changed by the effect of chemicals on surface tension and osmosis. For example, a positive change of surface tension by the action of chemicals will cause the biconcave cells to shrink into a roughly spherical, wrinkled and scalloped (crenated) shape. The above theoretical predictions are in qualitative agreement with known experimental facts. Professor Fung also demonstrated that the geometry of the crenated cells and the size and shape of the cell at rupture can yield important information with regard to the strength of the cell membrane. He strongly recommended that detailed records be made of the geometrical changes that occur in crenation, disc-sphere transformation, and rupture. Formulas are given which relate the ultimate stress, strain, and Young's modulus at the point of rupture.

Turning his attention to the dynamics of red blood cells in the blood plasma, Professor Fung considered the random impact on a cell of the macromolecules in the plasma, i.e., the Brownian motion of the molecules around the red blood cell. A random oscillation would be generated, which can be analyzed according to engineering methods. In particular, the lower models of vibration would reveal themselves. Professor Fung found that such a random motion had indeed been reported in the literature, and that this was called the "scintillation of the red cells" under a microscope. (10) The phenomenon consists in the fluctuation of light through the cell, which is particularly marked in the transparent central region. When this was examined in the laboratory recently, one

of Professor Fung's colleagues exclaimed, "I have seen this all my life, but all along I thought it was something wrong with my eyes." ★

REFERENCES

(1) Sacks, A. H., "Laminar Flow Regimes for Rigid Sphere Suspensions," AFOSR 66-0412, February 1966.

(2) van Driest, E. R., "Boundary-Layer Transition--Roughness and Free-Stream Turbulence Effects," AFOSR 4607, October 1962.

(3) van Driest, E. R., "Pressure Gradient Effects," AIAA Journal, Vol. I, pp. 1303-1306, June 1963.

(4) van Driest, E. R., "Recent Studies in Boundary-Layer Transition," AFOSR 64-0589, November 1963.

(5) Radbill, J. R. and E. R. van Driest, "A New Method for Prediction of Stability of Laminar Boundary Layers," AFOSR 66-0702, February 1966.

(6) Pomerantz, J., "Mechanics of Blood Vessels," OAR Research Review, Vol. IV, pp. 7-8, March 1965.

(7) Baez, S., A. Baez, and H. Lamport, "Pressure Effects in Living Microscopic Vessels," Flow Properties of Blood, Editors: A. A. Copley and G. Stainsky, London: Pergamon Press, Inc., 1960, p. 122.

(8) Fung, Y. C., B. Zweifach, and M. Intaglietta, "Elastic Environment of the Capillary Bed." Paper completed in December 1965. To be published in Journal of Circulation Research.

(9) Fung, Y. C., "Theoretical Considerations of the Elasticity of Red Blood Cells and Small Blood Vessels." Invited paper presented at the Annual Meeting of the Microcirculation Society. Scheduled for publication in the Symposium on Microcirculation: Federation Proceedings, 1966. (Federation of American Societies for Experimental Biology)

(10) Bessis, M., "Cytology of the Blood and Blood-Forming Organs," Translated by E. Ponder, New York: Grune and Stratton, 1956, p. 248.

HEAT TRANSFER AND RELATED SUPERSONIC FLOW STRUCTURE FOR AERODYNAMIC REARWARD-FACING SURFACE STEPS

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Because of the heat-transfer problems that have occurred in the base areas of rocket jets, and because of design interest in separated base flows and flows over non-smooth surfaces, such flow structures have had considerable attention in recent years. The theories of Crocco-Lees, Chapman, and Korst for the predictions of base pressure are based primarily on the viscous mixing process in the free shear layer and assume essentially dead air in the cavity. These theories have been in need of detailed experimental verification and extension, both inside and outside of the flow cavity. For several years Dr. Rom, of the Technion in Haifa, has been conducting a research program in this area for ARL. He measured base pressures and heat transfers in separated and reattaching flow over rearward-facing steps at Mach numbers of 2.25 and 3.50 and step position flow Reynolds numbers ranging from 1 to 2 times 10^5 (corresponding to flat-plate laminar flow) and from 0.6 to 5 times 10^6 (corresponding to flat-plate turbulent flow). He was able to develop some plausible correlation of his experimental pressure data with a modified Crocco-Lees theory, and also found some relatively high heat transfers in the reattachment region. His models were too small for flow-structure measurements. It was felt that his shock-tube heat-transfer measurements should be checked in an extended-time wind-tunnel facility, and that an extension in the Reynolds number range would be useful. An ARL in-house program was started to supplement the Technion program described above. This in-house experimental test program was conducted in Tunnel A of the Air Force Tullahoma Facility. It included total pressure and temperature pitot measurements throughout the flow structure, shadowgraph pictures, and surface static-pressure and heat-transfer measurements on a cooled model providing steady-state conditions. Also included were cavity-yarn and hot-wire measurements which, up to this point, have yielded only qualitative information.

The program has disclosed some very significant and unanticipated results. In Figure 1 we see the two lip shocks, or

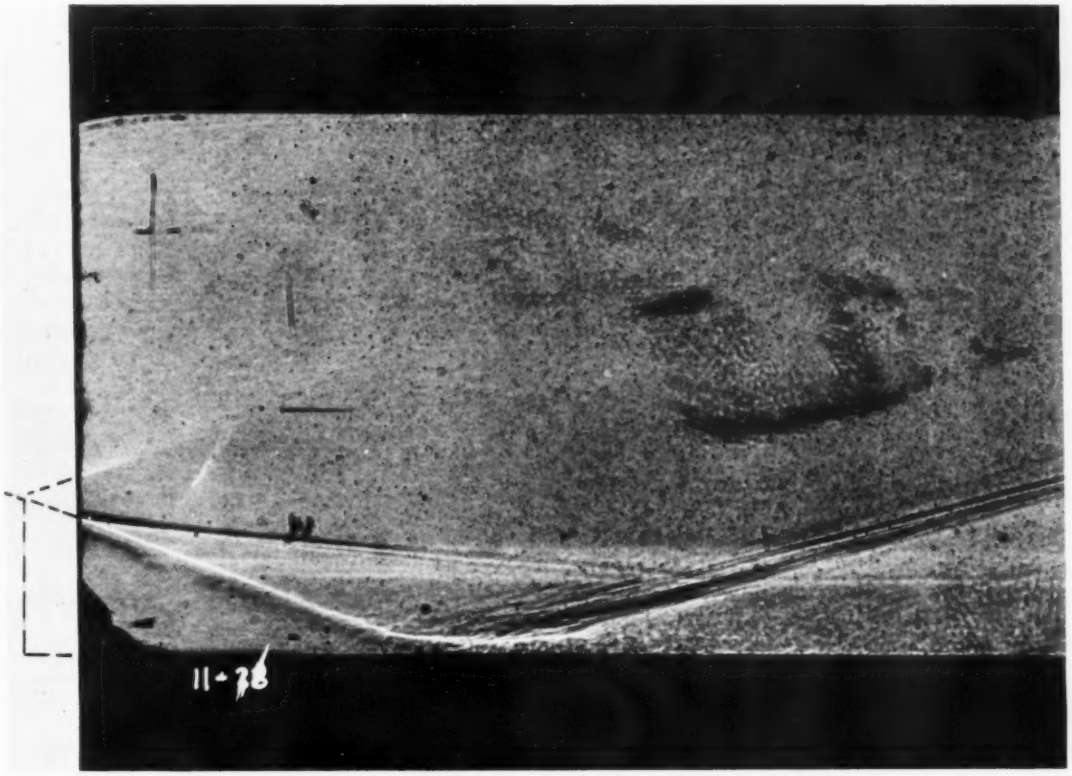

Figure 1. Shadowgraph of two lip shocks, or separation shocks.

separation shocks, that were observed in some of the shadowgraph pictures. The upper one emerges from step separation points and apparently is not very strong since it was not detected in the pressure-probe data. It is probably generated by the disturbed flow upstream of the separation point resulting from the influence in the subsonic part of the boundary layer of the reduced base pressure. The pressure-probe data would indicate that it does not have a great influence on the flow. The second separation shock emerges from the shear layer downstream of the separation point and is strong enough to be also observable in pressure data. At the lower Mach numbers it has rather strong total head losses as it comes from the shear layer; but the losses decay rather rapidly. This second separation shock can be important in the flow structure involved. Single separation shocks have been observed in earlier works. The earlier theories did not include the separation shocks. The stronger of these shocks is now predictable as a result of the entropy variations, in the boundary-layer flow, that arrive at the separation point. The bright line below the second separation shock starts at the top of the shear layer and becomes a part of the reattachment shock which realigns the flow towards the free-stream direction. This part of the reattachment shock is actually upstream of the flow reattachment, and has not been observed before. In the neighborhood of the reattachment region, the shock bends through an arc and takes an attitude normally observed and anticipated.

Another point of interest in Figure 1 is the slip line which emerges at the intersection of the second separation shock and the reattachment shock. This flow structure has

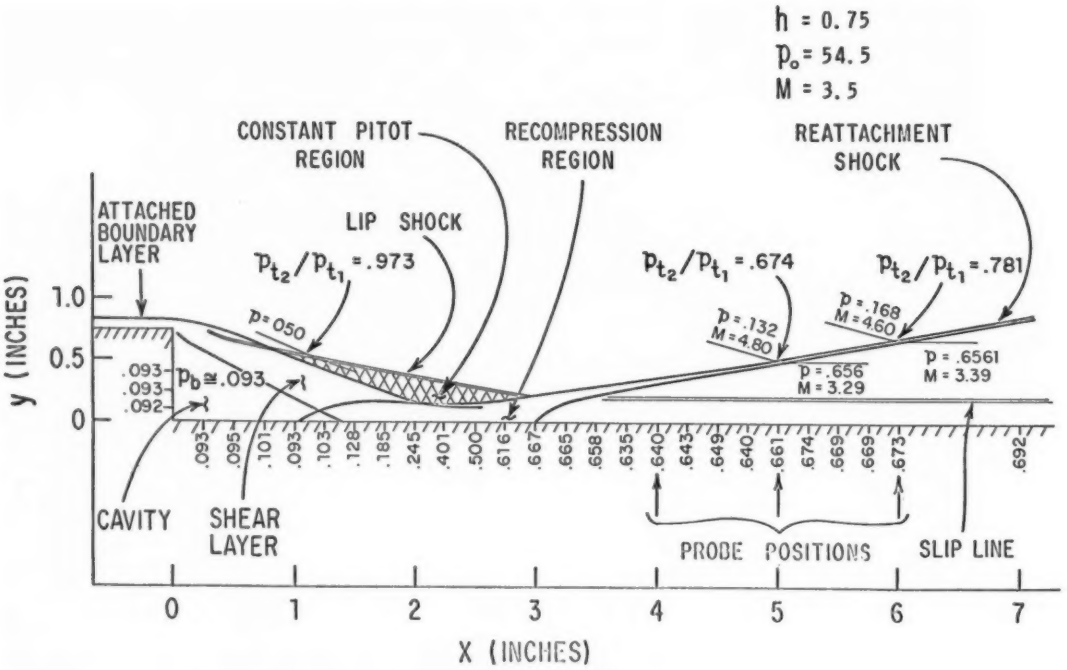

Figure 2. Some characteristics of supersonic flow structure.

rapid changes in speed and density and no changes in pressure.

Figure 2 is a detailed illustration of some of the characteristics that have been determined. It shows shock and shear-layer positions, shock total pressure changes (P_{t2}/P_{t1}), static pressures and Mach speeds.

For design interest it was found that, for the higher Mach speeds (3.5 and greater), the base pressure may be estimated from the Reynolds number based on the step height (h), and maximum heat transfers may also be estimated from this Reynolds number.

There is much more to be done, however, before a complete analytical model can be constructed. ★

REFERENCES

(1) Scherberg, M. G. and H. E. Smith, "Experimental Study of the Flow Structure and Heat Transfer for a Rearward-Facing Step in Supersonic Flow," Proceedings of the Eighth Israel Annual Conference on Aviation and Astronautics, February 1966.

(2) Scherberg, M. G. and H. E. Smith, "On the Supersonic Flow Structure for a Rearward-Facing Step," Proceedings of the Fifth US National Congress of Applied Mechanics, June 1966.

hypersonic flow research at ARL

DR. ROBERT H. KORKEGI
Hypersonic Research Laboratory, ARL

The research activity of ARL's Hypersonic Research Laboratory is designed to gain knowledge about basic phenomena in fluid and flight mechanics, with particular emphasis on the aerodynamics and the strong viscous effects associated with lifting and nonlifting hypersonic vehicle configurations.

The principal areas of research are:

(1) Aerodynamic stability of blunt-nosed slender bodies.

(2) Optimization of lifting re-entry configurations.

(3) Separated flows and viscous interactions.

(4) Rarefied gas studies.

The research discussed below highlights some of the "in-house" efforts.

Aerodynamic Stability

Research on aerodynamic stability at hypersonic speeds was stimulated by experience with actual flight vehicles during re-entry, and is co-ordinated with other Government agencies, universities, and industry through the "Technical Workshop on Hypersonic Dynamic Stability."

The Laboratory's work in this area, under the leadership of Mr. O. Walchner, centers on both experimental and theoretical studies of the stability characteristics of blunted slender cones at high Mach numbers.

Successful wind-tunnel measurements of static and dynamic stability derivatives in pitch, at various trim angles of attack and reduced frequencies, were made possible at high Mach numbers by the development of a model support system with torsion flexures yielding very low structural damping. The tests, utilizing the small-amplitude free-oscillation technique, were made in the ARL 20-inch hypersonic wind tunnel at a Mach number of 14 (1). The cone model with the flexures developed for the tests is shown in Fig. 1. An experimental study presently under way is designed to determine the phase lag of model surface pressures for blunt-nosed cones in pitching oscillations.

Analytical studies are directed toward obtaining better theoretical predictions of

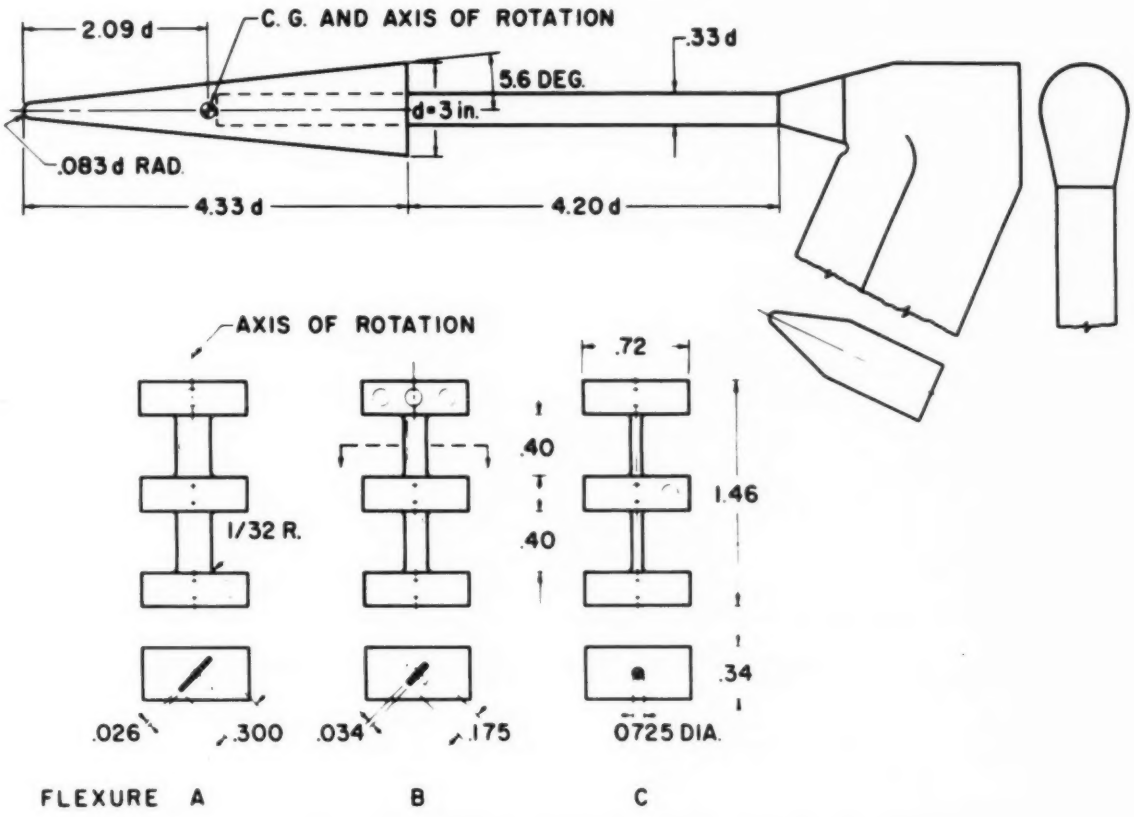

Figure 1. Cone model with flexures.

stability derivatives than the existing ones based on Newtonian flow which depart considerably from measured values for slender bodies with large nose bluntness. A semi-empirical analysis utilizing a tangent cone correction for angle of attack (2) has shown reasonably good agreement with experiment for static stability derivatives, but a significant departure in the dynamic stability derivatives for large nose bluntness. A new unsteady flow analysis for blunt-nosed slender cones in pitching oscillations, based on blast-wave theory (3), has overcome the previous theories' limitations and accurately predicts the dynamic stability derivatives for the large nose-bluntness regime with excellent agreement with the experimental results.

New research is planned toward studies of stability in roll and roll resonance for blunted slender cones, as well as studies of the effects of the boundary layer and ablation on stability.

Optimization of Lifting Re-entry Bodies

Interest in lifting re-entry bodies centers on the great potential advantage of the lateral and longitudinal maneuverability they possess over the simple drag bodies such as Mercury. Typical Air Force R&D projects in lifting re-entry include ASSET, and START.

Optimization studies of lifting re-entry bodies are being conducted under the leadership of Dr. W. L. Hankey. A systematic optimization study accounting for realistic flight mechanical (stability, landing) and aerothermodynamic (heating, skin-friction) constraints is geared toward achieving an efficient vehicle design with minimum structural weight and maximum hypersonic lift-to-drag ratio.

The first phase of research has resulted in the determination of configurations achieving the ultimate in hypersonic L/D in the absence of skin-friction, heating, stability and landing constraints. Results are shown in Fig. 2 in terms of volumetric efficiency,

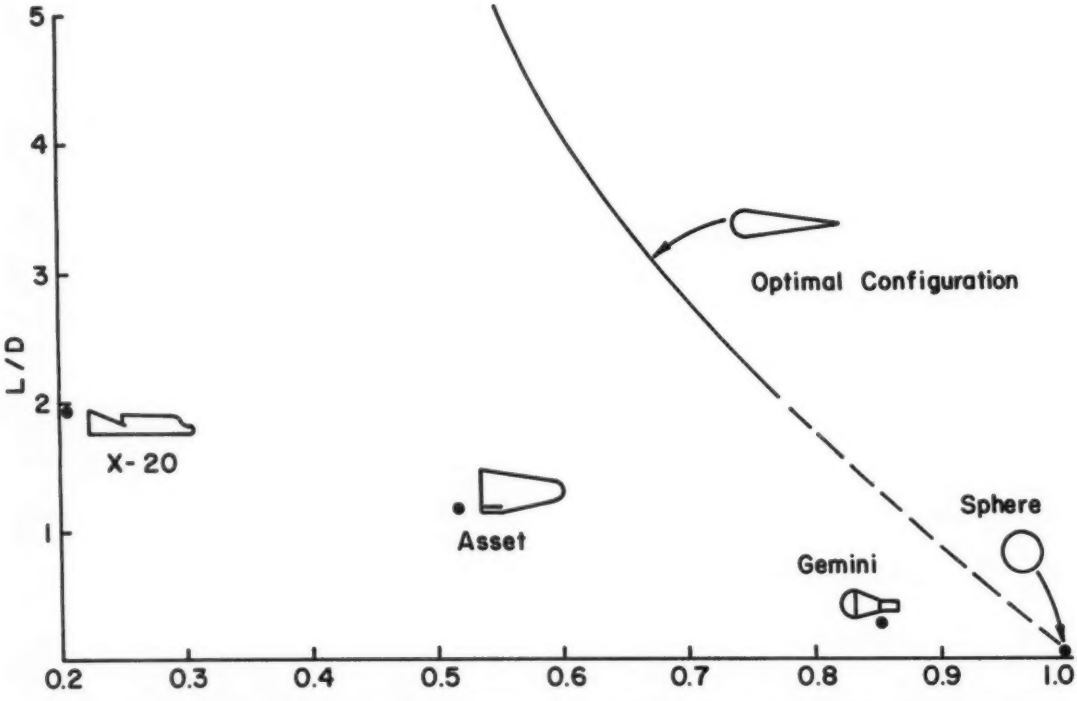

Figure 2. Hypersonic lift-to-drag ratios plotted against volumetric efficiency.

a parameter which reflects the structural efficiency of a configuration. Further studies have shown that heating and stability constraints result in only minor reductions in L/D, while the landing requirement appears to impose a severe performance penalty (4, 5). Theoretical predictions of L/D have been verified experimentally for several configurations of wedge-nosed cones with hemispherical base. The results of one phase of the optimization study were presented at the 1965 Air Force Science and Engineering Symposium, and led to the award for the best scientific presentation.

The importance of this research lies not only in the development of optimum vehicle configurations in an area where the weight penalty is so great, but also in giving a

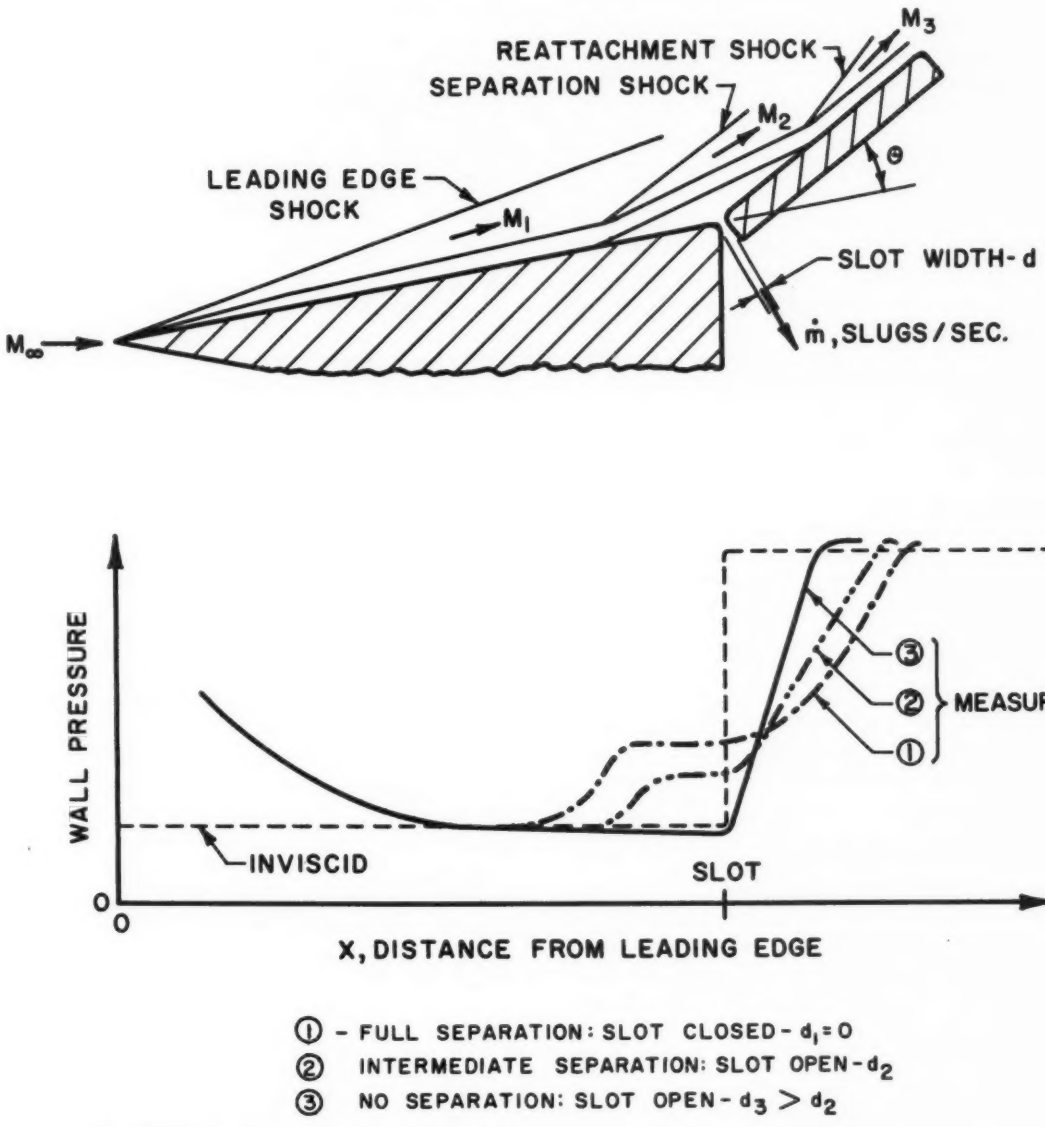

Figure 3. Decrease and eventual disappearance of separation zone with increasing suction.

qualitative indication of the influence of each individual constraint on the vehicle configuration, thereby providing much-needed practical guidelines for future designs. The optimization study is being extended to include an air-breathing propulsion system.

Separated Flows and Viscous Interactions

An aerospace vehicle travelling at high Mach numbers during any portion of its flight will be subjected to complex aerodynamic phenomena resulting from flow separation and viscous interactions.

The Hypersonic Research Laboratory is engaged in several experimental and theoretical efforts designed, on the one hand, to gain better knowledge of the development and the structure of boundary layers and criteria for flow separation at hypersonic speeds (of practical importance for the prediction of aerodynamic heating and skin friction) and, on the other hand, to gain basic knowledge of complex interactions related to lifting surfaces, and stabilizing and control components (flaps and fins) for lifting vehicles at hypersonic speeds. This research is being conducted under the leadership of myself and Dr. Hankey.

Analytical studies include the application of Dorodnitsyn's N-parameter method of integral relations toward a generalized solution of the laminar boundary-layer equations. The objective of this study was to obtain computational techniques for the solution of the laminar boundary-layer equations (6, 7), which can then be applied to investigate solutions to specific problems.

Two experimental studies deal with aerodynamic control surfaces related to hypersonic vehicles. One of these studies is designed to determine the control effectiveness of flaps (8), and the other encompasses an investigation of various shaped fins on a blunt flat plate (9, 10).

In view of the possibility of flow through the gap between a flap and wing from the compression to the expansion side, a basic investigation was undertaken in the ARL 20-inch Hypersonic Wind Tunnel of the effect of suction on flow separation on a wedge followed by a compression ramp, for various ramp angles. Mass suction was varied by varying the gap between wedge and ramp. The results of this investigation (11) show that the separation zone decreases markedly with increasing suction, and eventually vanishes (Fig. 3) for relatively small mass suction--about 1% of the boundary-layer mass flow.

Other investigations presently under way include a study of flow on the lee side of a delta wing at hypersonic speeds, and a detailed study of the flow structure resulting from the interaction of a blunt fin on a flat-plate boundary layer.

Rarefied Gas Studies

Flight at very high altitudes where the atmosphere is rarefied is of increasing interest to the Air Force, particularly in connection with the re-entry of potential lifting hypervelocity vehicles, and also to determine the orbital decay of satellites. At altitudes exceeding 300,000 feet, the atmospheric density is so low that there arise significant departures from continuum flow. Shock waves and shear layers spread out until they finally lose their identity in approaching the so-called "free-molecule" flow regime.

In-house research in the area of rarefied gases is theoretical and includes studies of the structure of a shock wave reflecting from a normal wall (12) (in connection with the development of shock tubes for low-density flow research, notably at Cal Tech and the USAF Academy), and the solution of the Boltzmann equation with a simple collision model for the classical Rayleigh problem (13, 14) -- the impulsively started infinite flat plate. The latter study has yielded solutions for the velocity profiles, wall shear and convective heat transfer in the transition region from free-molecule to continuum flow for the case where the velocity of the flat plate is much smaller than the mean molecular velocities. It is planned to extend this work to the case of large plate velocities.

In addition to "in-house" research, the Hypersonic Research Laboratory supports work in related areas through contracts with leading universities and research organizations, including the California Institute of Technology, Princeton University, New York University, and the Cornell Aeronautical Laboratory. ★

REFERENCES

(1) *Walchner, O., F. M. Sawyer and S. J. Koob, "A Study of Dynamic Stability Testing in a Mach-14 Blow-Down Wind Tunnel," Journal of Spacecraft and Rockets, Vol. 1, No. 4, Jul-Aug 64; also ARL 64-221.*

(2) *Walchner, O. and J. T. Clay, "Hypersonic Stability Derivatives of Blunted Slender Cones," AIAA Journal, Vol. 3, No. 4, April 1965; also ARL 65-150.*

(3) *Quinn, B. P., "Blast-Wave Effects on the Pitching of Blunt Cones." Presented at the 13th Annual Air Force Science and Engineering Symposium, AEDC, Sept 1966.*

(4) *Hankey, W. L. and L. J. Schroeder, "Optimization of Lifting Re-entry Bodies," Proceedings of 12th Annual Air Force Science and Engineering Symposium, Vol. 1, 1965.*

(5) *Hankey, W. L. and L. J. Schroeder, "Optimization of Hypersonic Lifting Bodies," OAR Research Review, Vol. V, No. 5, July 1966.*

(6) *Bethel, H. E., "On the Convergence and Exactness of the Laminar Boundary-Layer Equations Using the N-Parameter Integral Formulation of Galerkin-Kantorovich-Dorodnitsyn," ARL 66-0090.*

(7) *Bethel, H. E., "On the GKD Method for the Laminar Boundary-Layer Equations," OAR Research Review, Vol. V, No. 8, October 1966.*

(8) *Fiore, A., "An Investigation of Aerodynamic Controls at Hypersonic Mach Numbers," to be issued as an ARL report.*

(9) *Thomas, J. P., "Investigation of the Pressure Distribution on a Blunt-Fin Blunt-Plate Combination at a Mach Number of 11.26," ARL 66-0142.*

(10) *Thomas, J. P., "The Effect of Aerodynamic Control Surfaces on High-Speed Vehicles," OAR Research Review, Vol. V, No. 9, November 1966.*

(11) *Ball, K. O. W., ARL report in preparation.*

(12) *Petty, J. S., "Reflection of a Plane Shock Wave from a Normal Isothermal Wall," presented at the Fluid Dynamics Divisional Meeting, American Physical Society, 22-24 November 1965.*

(13) *Nagaraja, K. S., "The Linearized Rayleigh Problem in a Rarefied Gas Flow According to the BGK Model," to be issued as an ARL report.*

(14) *Nagaraja, K. S., "The Linearized Rayleigh Problem According to Kinetic Theory," OAR Research Review, Vol. V, No. 2, April 1966.*

Scientific Notes

Ionospheric Attenuation of Radio Signals: A Nike Iroquois (Niro) sounding rocket was launched by AFCRL from the Eglin Gulf Test Range in Florida on 3 October 1966 to measure attenuation of radio signals by the ionosphere. In this experiment, a 20 x 1-ft. toroidal (doughnut-shaped) balloon was released and inflated 80 seconds after launch at 300,000 feet. A metallic strip, serving as a receiving antenna, was wrapped around this balloon. Normal transmissions from a Pensacola radio station (980 kc) and an aircraft radio beacon (200 kc) were received. Ionospheric attenuation of these signals was measured over a vertical profile of the ionosphere up to the maximum altitude of about 140 km. Data were telemetered to ground receiving stations. The project scientist is Richard B. Harvey; the field director is Robert O. Harrison. (Upper Atmosphere Physics and Aerospace Instrumentation Laboratories)

Daytime Aurora: Three rockets were launched on 4 October 1966 from the Fort Churchill Research Range in Canada to study the D-region of the ionosphere during a daytime auroral event. A Black Brant and 2 Sidewinder Arcas rockets were used in the experiment. The Black Brant carried a pay load of 465 pounds, consisting of magnetometers, a photometer, a radiometer, retarding potential analyzers, a solar-horizon sensor, and a Gerdian condenser used for positive-ion measurements. The 2 Sidewinder Arcas rockets were fired in a secondary experiment to calibrate the Gerdian condensers. For this calibration, subsonic readings from the smaller Sidewinder Arcas rockets were compared with supersonic readings from the Black Brant. The Arcas vehicles reached 95 km. The Black Brant's apogee was 190 km. The project scientist for these experiments is John A. Sandock. (Upper Atmosphere Physics and Aerospace Instrumentation Laboratories)

Nike Cajun And C-130 Combine to Measure Sky Brightness: A Nike Cajun sounding rocket was launched from the Eglin Gulf Test Range on 5 October 1966 to measure sky radiance in 6 discrete spectral regions near the visible band between 3,750 to 5,550 angstroms. The vehicle carried a 70-pound pay load to an altitude of about 155 km. Instrumentation on the rocket consisted of 6 photometers, each having a narrow-band (75-angstroms) optical filter. One minute and 4 seconds into the flight, the nose tip was ejected, allowing the photometers to measure the zenith sky radiance for the duration of the flight. Concurrently with the rocket launch, an AFCRL C-130 aircraft made optical measurements over the same spectral region for comparison with the rocket measurements. The project scientist is Robert B. Toolin. (Optical Physics and Aerospace Instrumentation Laboratories)

Atmospheric Density: Two Nike Iroquois (Niros) were launched from the Eglin Gulf Test Range on 11 October 1966 to measure atmospheric density from 95 to 140 km. The rockets released 3-foot balloons at an altitude of 200 km where the balloons began a free fall. Each balloon contained a 3-axis accelerometer to measure drag deceleration. Data were telemetered to the ground. On the same day, AFCRL tested 2 Sparrow Arcas rockets as possible replacements for the Niros on future atmospheric-density experiments. The Sparrow Arcas rockets are smaller and less costly than the Niro rockets. The project scientist for the experiments is Gerard A. Faucher. (Aerospace Instrumentation Laboratory)

New Rocket-Borne IR Spectrometer Used for Moon Survey: An Aerobee-150 rocket was launched on 29 October 1966 from the White Sands Missile Range in New Mexico to obtain infrared spectral information from the moon. Instrumentation on the rocket included a lunar pointing control device, and a spectrometer. The spectrometer is much smaller, lighter and more reliable than any previously used. It has a device, called a Circular Variable Filter, mounted on a motor-driven disc in front of the lens. This feature gives much higher resolution without the necessity for mechanical scanning. Payload weight for the vehicle was 75 pounds. The rocket reached an altitude of about 250 km. The project scientist is Dr. John W. Salisbury. (Space Physics and Aerospace Instrumentation Laboratories) ★

climatic extremes and a 500-foot radome

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

Engineering work on a 500-foot radome logically starts with data on climatic extremes--snowfall, rain, winds, and so on--that could be expected at the location of the radome. Such data are more important in designing a radome than for other large structures because the mass of the radome must be kept at a minimum to avoid undue attenuation of radio waves passing through it.

When the Cambridge Radio Observatory Committee, set up by MIT, the Lincoln Laboratory, Harvard, and the Smithsonian Astrophysical Observatory, began last year to investigate the feasibility of a large, new radio observatory in the Boston area, climate was a major initial consideration. AFCRL was asked by the Observatory Committee to supply data on climatic extremes within the general commuting area of Boston (two hours' surface travel).

Norman Sissenwine and Irving I. Gringorten of AFCRL have recently completed and submitted a report to the Observatory Committee on the climatic extremes for this area. The study covers extremes of rain, temperature, snow, hail, icing, wind and wind gusts, and gives the odds that a given climatological condition will be reached or exceeded during the 25-year expected lifetime of the radome. Some of the findings are given below.

Rainfall: The heaviest rainfall recorded in the Boston area in the past 65 years for any given hour was 2.10 inches although, for a 5-minute period, the rate was 6.72 inches per hour. There is only a 1-per cent probability that during the next 25 years more than 3.09 inches of rain will fall during any 1 hour, or that the Boston area will witness

a Niagara-like torrent of a 12-inch rate during any 5-minute period.

Extremes of Cold: In considering temperature extremes, Sissenwine and Gringorten used the 30-year records of 11 New England Weather Bureau stations. Taking the coldest period of the year, January 1 through February 1, we find that the mean temperature for these 32 days is 25.4 degrees F. For any given year, there is a 50-per cent probability that the temperature will drop as low as minus 4 degrees F, and a 2-per cent probability that it will go as low as minus 15 degrees. But for a 25-year period, there is a 50-per cent probability that the temperature will go below minus 15 degrees F at some given time, and 2-per cent probability that it will go below minus 23 degrees F.

Extremes of Heat: The July average at the 11 New England stations gives a typical station mean of 70.6 degrees F. (Boston's readings are taken at Logan Airport, however, where the mean is 72.2 degrees F.) In any given year, there is a 50-per cent probability that the temperature will exceed 92 degrees F (as it did in 1966), but only a 1-per cent probability that it will exceed 102 degrees F. For a 25-year period, there is a 50-per cent probability that the temperature will exceed 100 degrees F at least once, and a 2-per cent probability that it will exceed 107 degrees F.

Snowfall Extremes: In 35 years, the average heaviest-of-the-year snowfall in Boston was 9.9 inches in 24 hours. In a 25-year period, however, we might expect a maximum of 18.9 inches in 24 hours, with a 1-per cent probability that during at least one 24-hour period there will be a 30-inch snowfall.

Winds and Wind Gusts: Data on winds and wind gusts are more difficult to analyze statistically than other climatological data. Averages vary with coastal and inland areas, in cities and adjacent airports, and with height above the ground. Furthermore, it is necessary to distinguish between persistent winds of at least five-minutes' duration and gusts which last a few seconds. Yet, from the standpoint of designing a low-mass radome, winds are the single most important climatological factor.

In their report, Sissenwine and Gringorten devote more space to winds and to techniques for their analysis than to any other aspect of climate that might affect the radome. Although Mt. Washington, in New Hampshire, was not included in their 8-station study, they note in passing that the strongest wind of record any place in the world occurred in 1934 atop Mt. Washington--a wind of 188 mph. The highest 5-minute wind speed recorded in the 8-station study was 95 mph at Providence, Rhode Island, during the 1938 hurricane.

Winds are discussed in terms of 5-minute averages. To these 5-minute winds, they add a gust factor, which varies with height above the ground. For example, if winds are measured at an elevation of 10 feet, the gust factor at this altitude is calculated to be 1.7. Wind speeds increase with altitude, and at the same time the gust factor decreases.

Following is a summary of the probability estimates for the maximum 5-minute winds over 25 years, averaged for the 3 coastal stations (Boston, Nantucket and Portland) and for 5 inland stations:

Ht. Above Ground	Coastal			Inland		
	50%	1%	0.1%	50%	1%	0.1%
50 ft.	72	112	130	55	82	96
100 ft.	80	124	144	61	91	107
250 ft.	91	141	164	69	103	121
500 ft.	99	153	178	75	112	132

Hail and Icing: A given location in New England is subject to a hailstorm about 1.1 times a year near the coast and 1.2 times a year inland. The largest hailstones for the average storm are about a quarter inch. But over a 5-year period, hailstones as large as 1.5 inches have been reported 5 times; and there is one report during this period of a 3-inch hailstone. After analyzing the icing problem, Sissenwine and Gringorten conclude that the radome engineer should design the radome to support a weight of 1 inch of clear ice (56 pounds per cubic foot) on a horizontal surface, and 2 inches on vertical surfaces.

PROFILES

Dr. Robert H. Korkegi, Director of the Hypersonic Research Laboratory, joined ARL in 1964 after almost 7 years in Brussels, Belgium, as Technical Director of the von Karman Institute for Fluid Dynamics. During the summer of 1956, as a consultant to the Advisory Group for Aeronautical Research and Development (AGARD-NATO), he lectured on research in hypersonic aerodynamics and advised on the planning of hypersonic facilities in France and Belgium. He received his B.S. in Mechanical Engineering from Lehigh University in 1949, and his M.S. and Ph.D. in Aeronautical Engineering, both from the California Institute of Technology, in 1950 and 1954, respectively. Dr. Korkegi has a number of publications to his credit. His article on "Hypersonic Flow Research at ARL" appears in this issue of the Review.

Dr. Max G. Scherberg is presently at ARL's Thermomechanics Research Laboratory as an Aerospace Research Engineer. He is currently assigned as a research leader for basic investigations in heat-transfer phenomena, particularly under conditions of unsteady flow similar to those encountered in flight by aircraft and missiles. In this issue of the Review, he writes on "Heat Transfer and Related Supersonic Flow Structure for Aerodynamic Rearward-Facing Surface Steps."

Dr. Scherberg came to the Aerospace Research Laboratories (then the Aeronautical Research Laboratories) in August, 1953. He served in Fluid Mechanics, Solid Mechanics and Applied Mathematics as a laboratory research manager until March, 1961, when he was assigned as a research physicist in his present position. Dr. Scherberg received his B.S. in Chemical Engineering from Washington University in 1925, and his Ph.D. in Mathematics and Physics from the University of Minnesota in 1931. He has a great number of publications to his credit.

Mr. Irving I. Gringorten is an atmospheric physicist with the Design Climatology Branch, Aerospace Instrumentation Laboratory, AFCRL. He has been with AFCRL or its predecessor organizations since 1947, and is engaged in work on applied climatology. Currently, he is considering the problems of extreme value statistics, ballistic wind estimations, applications of the Markov chain and methods of least squares to probability distributions of meteorological parameters such as cloud cover and types. Mr. Gringorten has a B.A. with First Class Honors (1935) and an M.A. (1936), both from the University of Toronto. He took advanced studies at the California Institute of Technology from 1937 to 1940. "Climatic Extremes and a 500-Foot Radome," in this issue of the Review, describes the results of a climate study of the Boston area by Mr. Gringorten and Mr. Norman Sissenwine.

Mr. Marshall B. Patterson, an electronics engineer with the Aerospace Instrumentation Laboratory, AFCRL, is the author of "Rocket Tracking Systems for Launchings in Remote Locations" in this issue of the Review. He attended Monmouth Junior College, Boston University, and George Washington University. From 1949 to 1955, he was with the Army Signal Corps, where he participated in the design and development of JAN-type vacuum tubes and engaged in operational analysis of communications countermeasures. From 1955 to 1958, Mr. Patterson was responsible for a complex of operations in the central link of the Integrated Gulf Testing Range, at Eglin AFB, Florida. Since coming to AFCRL in 1958, he has been working in tracking, range safety, and telemetry.

Mr. Norman Sissenwine has been Chief of the Design Climatology Branch and senior scientist in the Aerospace Instrumentation Laboratory, AFCRL, since 1963. He joined AFCRC, AFCRL's predecessor, in 1953, serving in responsible positions from the very beginning. He earned his B.S. in Meteorology (1948) "with distinction" at New York University. Mr. Sissenwine is considered an expert on wind and density profiles as related to the vertical flight of missile systems, and is responsible for many of the techniques currently used to evaluate the performance of these systems. He holds several patents, and has received a number of awards for outstanding service to the Government. The article, "Climatic Extremes and a 500-Foot Radome," in this issue of the Review, describes the results of a climate study of the Boston area that was conducted by Mr. Sissenwine and Mr. Irving I. Gringorten.

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